Smith, M. C., Ben-Shlomo, Y., Dieppe, P., Beswick, A. D., Wilkinson, J. M., & Blom, A. W. (2017). Rates of hip and knee joint replacement amongst different ethnic groups in England: An analysis of National Joint Registry data. *Osteoarthritis and Cartilage*, *25*(4), 448-454. https://doi.org/10.1016/j.joca.2016.12.030

Rates of hip and knee joint replacement amongst different ethnic groups in England: An analysis of National Joint Registry data

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Key words: Ethnicity; Hip replacement; Knee replacement; England

Word count: 2,483 words

Abstract

Objective: Despite a health care system that is free at the point of delivery, ethnic minorities may not always get care equitable to that of White patients in England. We examined whether ethnic differences exist in joint replacement rates and surgical practice in England.

Design*:* 373,613 hip and 428,936 knee National Joint Registry primary replacement patients had coded ethnicity in Hospital Episode Statistics. Age and gender adjusted observed/expected ratios of hip and knee replacements amongst ethnic groups were compared using indirect standardisation. Associations between ethnic group and type of procedure were explored and effects of demographic, clinical and hospital-related factors examined using multivariable logistic regression.

Results: Adjusted standardised observed/expected ratios were substantially lower in Blacks and Asians than Whites for hip replacement (Blacks 0·33 [95% CI, 0·31 to 0·35], Asians 0·20 [CI, 0·19 to 0·21]) and knee replacement (Blacks 0·64 [CI, 0·61 to 0·67], Asians 0·86 % [CI, 0·84 to 0·88]). Blacks were more likely to receive uncemented hip replacements (Blacks 52%, Whites 37%, Asians 44%; P<0·001). Black men and women aged <70 years were less likely to receive unicondylar or patellofemoral knee replacements than Whites (men 10% vs 15%, P=0·001; women 6% vs 14%, P<0·001). After adjustment for demographic, clinical and hospital-related factors, Blacks were more likely to receive uncemented hip replacement (OR 1·43 [CI, 1·11 to 1·84]).

Conclusions: In England, hip and knee replacement rates and prosthesis type given differ amongst ethnic groups. Whether these reflect differences in clinical need or differential access to treatment requires urgent investigation.

INTRODUCTION

Variations in the provision of health care interventions in different groups within society are commonplace.[1] In the USA particular concern has been raised about ethnicity, and the relative under-provision of certain procedures amongst African Americans. In the UK the major issue investigated has been reduced service utilisation amongst socio-economically deprived groups, [2,3] although ethnic minority groups are often located in the most deprived areas of a community.[4]

Hip and knee joint replacement operations are amongst the highest volume health care interventions worldwide. In England and Wales in 2013, 79,088 hip and 85,128 knee primary replacements were recorded on the National Joint Registry.[5] Osteoarthritis is the most common indication for joint replacement, with about 91% of total hip joint replacements and 98% of total knee joint replacements being done for this reason. In the USA recent studies have shown that, despite broadly similar osteoarthritis prevalence (age adjusted prevalence rates for Whites was 22·3% and Blacks 21·8%),[6] African Americans are less likely to get joint replacements than White Americans.[7-9] Various reasons have been postulated to explain this, including late presentation and relative unwillingness to undergo surgery amongst Black Americans.[10-14] In the UK and USA it has been shown that people in the most deprived groups are less likely to receive joint replacements than those of higher socio-economic status,[2,15] and at least one US study has suggested that there may also be racial disparities.[16] However, there has been no large-scale investigation of ethnicity and joint replacement in the UK.

We have used data from the National Joint Registry (NJR)[5], linked to the Hospital Episode Statistics (HES) database, to address whether the rate of primary hip and knee joint replacement is the same amongst different ethnic groups in England, whether there are differences in the clinical indications for primary joint replacement amongst ethnic groups and if types of prosthesis and fixation methods used differ between ethnic groups.

METHODS

We linked all records of primary knee and hip joint replacements in the NJR database for England and Wales and which took place between April 2003 and December 2012 to HES records of patient admissions for NHS funded care in England. In so doing, we obtained additional HES recorded patient demographic information on ethnic group and the geographical area in which the person lived – Lower Super Output Area Level (LSOAL). We

only used the first primary procedure recorded for a patient and excluded any revisions or subsequent primary procedure on the contra-lateral side for these patients.

Ethnicity exposure

Each NJR record was linked to all existing HES episodes of admission for that individual since 2001 to minimise missing data on ethnicity (HES changed the way ethnicity was categorised from 2001. To ensure consistency in ethnic groupings, we limited eligible HES records for linkage to the NJR to those from 2001 onwards). If the coding of ethnicity differed across episodes we used the most frequently indicated ethnic category. The numbers of patients in some ethnic groups was small, therefore for this data analysis, the ethnic groups were categorised into three main groupings: White (including British, Irish, Gypsy, and Other White), Black (including Caribbean, African, Mixed White & Black African/Caribbean, and Other Black origin), and other ethnicities (including Indian, British Indian, Pakistani, British Pakistani, Bangladeshi, British Bangladeshi, Mixed White & Asian, and Other Asian, Chinese, and "other mixed race"). We have labelled the last category "Asian" for simplicity and as this is the largest ethnic group amongst the races included here, even though it is clearly heterogeneous.

Other covariates

The residential postcode for the patient at the time of the primary operation was used to determine the English Index of Multiple Deprivation (IMD) 2010 area score by LSOAL as an ecological measure of deprivation.[17] We created a five-category indicator going from the 20% most deprived (quintile 1) to 20% least deprived areas of England (quintile 5) by ranking the IMD scores and categorising the distribution into quintiles. Other covariates included age group (<40, 40–49, 50–59, 60–69, 70–79, ≥80 years), gender, the American Society of Anaesthesiologists (ASA) six point scale of surgical fitness, and pre-operative functional severity as captured by the EQ-5D-3L[18] mobility item (whether they have 'no' or 'some' problems in walking about or are 'confined to bed') coded as a 3-level ordinal variable. We created a four level variable for body mass index (BMI) although this was only used in a sensitivity analysis due to a high proportion of missing data; underweight ($10 \leq BMI < 20$ kg/m^2), normal ($20 \leq BMI < 25$ kg/m^2), overweight ($25 \leq BMI < 30$ kg/m^2), and obese ($30 \leq BMI < 60$ kg/m^2). We also looked at type of prosthesis and method of fixation as clinical outcomes.

Statistical methods

We used indirect standardisation to compare the observed number of primary joint replacements, for any indication, to the expected numbers in each ethnic group, using the total age and gender specific risks of a procedure applied to the same ethnic specific population strata as reported in the 2011 Census data.[19] We explored possible differences in the clinical indications for having a primary joint replacement amongst ethnic groups using χ^2 tests of association.

Subsequent analyses were restricted to the sub-set of patients with osteoarthritis as the indication for the primary procedure. We used χ^2 tests to compare differences in categorical variables by ethnicity and in some cases stratified by gender. Where the data suggested possible interactions, we used log-linear models assuming a Poisson distribution to test for this by comparing any improvement in goodness of fit of the models from likelihood ratio tests with and without these terms.

We ran both univariable and multivariable logistic regression models to mutually adjust for covariates. Model A simply examined ethnicity alone; model B adjusted for age-group, gender, ASA grade and area deprivation quintile as patient related confounders; model C adjusted for routine surgical behaviour unrelated to patient factors, by adjusting for what proportion of all hip replacements are done using uncemented prostheses at that trust. We took into account the clustering of procedures within a trust by using robust standard errors. We used Wald tests to determine the overall significance of additional terms added to a proposed model compared to the model without them. We undertook two further sensitivity analyses by comparing the results for model C with and without adjustment for pre-operative functional limitations using EQ-5D-3L mobility item (data available on about 30% of patients) and BMI (data available on about 45% of patients).

RESULTS

The total number of eligible NJR records available for all primary diagnoses for the period 2003–2012 before matching to HES and after excluding Welsh and non-NHS England funded operations for hips and knees were 425,726 and 481,528 primary replacements respectively. Of these, 12% hip and 11% knee replacements had missing ethnicity information either because a match to a valid HES record could not be made or because their HES ethnic group classification was ‘unknown’. This left 373,613 hip and 428,936 knee primary replacement records for any primary diagnosis with available ethnicity data. This was reduced to 330,384

hip and 362,505 knee patients after restricting to the first replaced side of a joint for those with bilateral operations. The total number of patients in the osteoarthritis only analysis sample, after restricting to patients' first primary replaced side and to those with a sole diagnosis of osteoarthritis, with valid ethnicity data was 640,355 (293,325 hip and 347,030 knee patients).

Table 1 shows the observed versus expected numbers of patients having a primary hip or knee joint replacement by ethnicity and stratified by gender. For both hip and knee replacements, there were fewer than expected procedures amongst the Black and Asian populations though this was far more marked for hip replacements. For hips, the ratio of observed to expected first replacements was very similar for both men and women, but for knees there were markedly fewer than expected procedures carried out on men compared to women.

(INSERT TABLE 1 HERE)

Osteoarthritis was the dominant indication in all three ethnic groups for both knee and hip replacement (table 2). There was some evidence that Black and Asians have a higher chance of having a knee replacement for inflammatory arthritis compared to Whites (p=0·02). For hip replacement, Black and Asians were more likely to have the procedure undertaken for avascular necrosis, inflammatory arthritis, congenital dysplasia, and 'other reasons'.

(INSERT TABLE 2 HERE)

Patients from ethnic minority groups having either hip or knee replacement for osteoarthritis were more likely to be younger and living in more deprived areas and, for hip replacements, were fitter as measured by the ASA grade (table 3).

(INSERT TABLE 3 HERE)

Because of these age differences we then examined if the type of fixation method used for either hip or knee replacement differed by age-group (<70, ≥ 70 years), gender and ethnicity (table 4). Both Black men and women were more likely to get uncemented hip prostheses regardless of age-group. For knee replacements, Black and Asians were less likely to get a patellofemoral or unicondylar prosthesis, though this was more marked for Black patients and in the younger age-group.

(INSERT TABLE 4 HERE)

We explored the possible reasons why Blacks were more likely to receive an uncemented hip prosthesis by testing different models (table 5).

(INSERT TABLE 5 HERE)

With regard to the odds of receiving an uncemented prosthesis, after adjustment for demographic variables and ASA grade, the elevated odds ratio for Asians (1·60) was markedly attenuated (1·21, 95% CI 0·90–1·63) and consistent with chance, whilst the odds ratio for Black patients remains elevated (1·86, 95% CI 1·30–2·66), albeit weaker. Further adjustment for surgical behaviour at trust level further attenuated the associations, but there still remained a 43% relative elevated odds (95% CI 1·11–1·84). Our sensitivity analyses showed that the odds ratios for Blacks and Asians of receiving an uncemented prosthesis for model C hardly changed after the addition of the EQ-5D-3L mobility item and BMI (odds ratio remained at 1·32 for Blacks and 1·12 for Asians) although in this smaller sub-set of the data (n=44,001) the 95% confidence intervals for these included the null value so could have occurred by chance (see table 6).

(INSERT TABLE 6 HERE)

DISCUSSION

Two important observations emerge from this study. Firstly, we have found that large ethnic variations in the rate of total joint replacement across ethnic groups are not explained by age and gender differences. These variations are greater for hip than knee replacement. For hip replacement, this difference is more marked for Asian than Black patients, whilst for knee replacement the difference is reversed, being more marked for Black people but with both ethnic minorities showing gender differences so that men are less likely to have received a joint replacement compared to women. The second observation is that there are unexpected differences in the types of prosthesis and fixation methods used between the ethnic groups, with greater use of uncemented hip prostheses amongst black minority groups in particular, as well as greater use of hip resurfacing in ethnic minorities, and less use of unicondylar or patellofemoral knee replacements. The surprising difference in use of the more expensive uncemented hip prostheses seems to be partially explained by the fact that ethnic minority groups are more likely to have their joint replacement in NHS hospital Trusts that are high users of uncemented prostheses.

Inequalities in the rates of joint replacement between ethnic groups have been described in the USA, Canada, Australia, and the UK.[2,7,20,21] It has also been observed that people in the most deprived socio-economic groups are less likely to receive a joint replacement.[2,21,22] This is the first large-scale study to confirm that in the UK, as in other countries, ethnic minorities are less likely to receive hip or knee joint replacements than the White majority. Unlike in the USA, health care in the UK is universal, so that the challenges faced by many US-based studies with respect to health insurance coverage would not affect these results, yet the findings are similar to those in the USA. Inequalities (differences) in utilisation are not synonymous with inequities in provision. There are many possible explanations for the differences observed, including variations in the prevalence of disease (particularly osteoarthritis, the dominant condition leading to hip or knee joint replacement), and differences in willingness to undergo surgery amongst the different ethnic groups.[10] Patient willingness to undergo surgery might be shaped by cultural factors, doctor-patient communication, variations in patient outcomes, or even issues related to patient trust in the healthcare system.

Whilst we were able to adjust for the age and gender distributions of the main ethnic groups using the Census data, the true denominator should be the number of people with a clinical indication for joint replacement and we have not been able to identify any data on the relative prevalence of osteoarthritis in the different ethnic groups in England. The major risk factors for OA are age, obesity, and joint injury. Some differences in osteoarthritis prevalence in ethnic groups have been observed but rates in US Black and White people are broadly similar.[7,23,24] It seems unlikely that ethnic differences in the prevalence of osteoarthritis account for all of the large difference in the rates of joint replacement we have observed. It is interesting to note the large gender differences in rates of knee replacement amongst the non-White groups with males much less likely to undergo joint replacement than females. This observation requires further investigation and may reflect ethnic and gender differences in delay in presentation or willingness to undergo surgery.

The findings surrounding the use of prosthesis and fixation type in different ethnic groups are intriguing. We were surprised by the higher use of uncemented hip prostheses amongst the Black and Asian groups compared with Whites and decided to investigate why that might be by use of models that factored demographic, surgical and trust related variables. We showed that the hospital in which people are operated on is a major determinant of the differences in hip replacement fixation method, as large, urban hospitals that serve a greater proportion of

these ethnic minorities tend to use a greater number of uncemented hip prostheses, though this is did not fully explain the differences for Black patients.

Similarly it is interesting to note that Black patients, when they present for surgery, are less likely to receive unicondylar or patellofemoral knee replacements.

The major strength of this analysis is the very large dataset available as the NJR is the largest joint replacement registry in the world. However, there are several important limitations. There is some misclassification of ethnicity, and ethnicity was missing from about 12% of records which may have biased the results, though in general missing data is more a trust-level rather than patient characteristic.[25] As mentioned above we have no data on clinical need so our observation of lower rates of joint replacement amongst ethnic minorities compared to White patients' needs to be treated with caution until we better understand the epidemiology of osteoarthritis in ethnic minorities in England.

In conclusion, we have shown that there are large differences in the utilisation of total hip and knee joint replacement in different ethnic groups in England, and in the types of prosthesis and fixation used. There are also marked gender differences within non-White groups of utilisation of knee replacement. We believe that this is probably explained by a combination of different factors, including deprivation, prevalence of osteoarthritis, and inequitable access to health care either because of ethnic differences in seeking care and willingness to undergo surgery or in differential clinical behaviour in surgical referral and prioritization for surgical intervention. At this stage we remain unclear as to the relevant importance of each of these factors and further research should elucidate whether interventions are required to ensure more equitable care.

Author contributions: All authors were involved in study design. Data management and all analyses were undertaken by MCS. YB-S, PD, MCS, JMW and AWB contributed to data interpretation. All authors contributed to preparation of the manuscript.

Funding Source: National Joint Registry for England, Wales, Northern Ireland, and the Isle of Man

Conflicts of interest: Stryker and DePuy have funded other research undertaken by the University of Bristol.

Acknowledgements: We thank the patients and staff of all the hospitals who have contributed data to the National Joint Registry. We are grateful to the Healthcare Quality Improvement Partnership (HQIP), the National Joint Registry Steering Committee (NJRSC), and staff at the NJR Centre for facilitating this work. The views expressed represent those of the authors and do not necessarily reflect those of the NJRSC or HQIP who do not vouch for how the information is presented.

Role of the funding source: The National Joint Registry, who sponsored the study, had no role in the study design, data collection, data analysis, data interpretation, or writing of the final report. MCS had full access to all the data in the study and AWB had final responsibility for the decision to submit for publication.

AWB and JMW assert, on behalf of the authors, that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted.

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TABLE LEGENDS

Table 1 Observed and expected number of patients presenting, for the first time, for primary hip/knee replacement for all causes in English NHS hospitals by ethnic group

Table 2 Clinical indications for hip and knee primary replacement patients by ethnic group

Table 3 Patient characteristics at time of first primary hip and knee joint surgery, broken down by ethnic group and gender, for patients with a primary diagnosis of osteoarthritis only

Table 4 Prosthesis fixation method for osteoarthritis first hip and knee replacement patients stratified by age-group, gender and ethnic group*

Table 5 Odds ratios for receiving an uncemented hip replacement by ethnic group adjusting for patient and trust related covariates (n=224,561)

Table 6 Logistic regression Models A-E with restricted sample size for BMI subset (n= 44,001)

Table 1 Observed and expected number of patients presenting, for the first time, for primary hip/knee replacement for all causes in English NHS hospitals by ethnic group

	All NJR	White			Black*			Asian*		
		NJR		Standardised Ratio (95%CI)	NJR		Standardised Ratio (95%CI)	NJR		Standardised Ratio (95%CI)
	Obs	Obs	*Exp*	Obs/Exp	Obs	*Exp*	Obs/Exp	Obs	*Exp*	Obs/Exp
Hip replacement patients†										
Total: Females NJR	195,800	195,800	*186,698*	1·05 (1·04–1·05)	1,166	*3,735*	0·31 (0·30–0·33)	1,588	8,122	0·20 (0·19–0·21)
Total: Males NJR	129,662	129,662	*123,102*	1·05 (1·05–1·06)	904	*2,557*	0·35 (0·33–0·38)	1,262	6,170	0·21 (0·19–0·22)
Total	330,382	325,462	309,800	1·05 (1·05–1·06)	2,070	6,292	0·33 (0·31–0·35)	2,850	14,292	0·20 (0·19–0·21)
Knee replacement patients‡										
Total: Females NJR	196,143	196,143	195,688	1·00 (1·00–1·01)	3,068	3,756	0·82 (0·79–0·85)	8,495	8,204	1·03 (1·01–1·05)
Total: Males NJR	149,636	149,636	145,592	1·03 (1·02–1·03)	1,044	2,670	0·39 (0·37–0·42)	4,117	6,535	0·63 (0·61–0·65)
Total	362,503	345,779	341,280	1·01 (1·01–1·02)	4,112	6,426	0·64 (0·61–0·67)	12,612	14,739	0·86 (0·84–0·88)

* Based on the Census 2011 main ethnic categories; Black = Black/African/Caribbean/Black British/Mixed White & Black African/Caribbean, Asian= Asian/Asian British/Mixed White & Asian/Mixed Other/Chinese and other groups·

† Hip observed/expected cases based on people aged 10 and over· ‡ Knee observed/expected cases based on census and NJR cases aged 15 and over·

Table 2 Clinical indications for hip and knee primary replacement patients by ethnic group

Reason for Hip replacement	*Number (%) of hip patients with specified primary diagnosis*[*] White (n= 325,461)	Black (n= 2,070)	Asian (n= 2,852)	p-value
Osteoarthritis	300,936 (92·5)	1,645 (79·5)	2,144 (74·1)	<0·001
Inflammatory Arthritis[†]	5,096 (1·6)	47 (2·3)	130 (4·6)	<0·001
Avascular Necrosis	8,500 (2·6)	289 (14·0)	277 (9·7)	<0·001
Congenital Dysplasia of Hip	5,135 (1·6)	99 (4·8)	142 (5·0)	<0·001
All Trauma [‡]	11,507 (3·5)	70 (3·4)	252 (8·8)	<0·001
Other hip reasons[§]	7,757 (2·4)	136 (6·6)	180 (6·3)	<0·001
Reason for Knee replacement	*Number (%) of knee patients with specified primary diagnosis*[*] White (n= 345,780)	Black (n= 4,112)	Asian (n= 12,612)	p-value
Osteoarthritis	335,258 (97·0)	3,961 (96·3)	12,209 (96·8)	0·04
Inflammatory Arthritis[‖]	8,609 (2·5)	128 (3·1)	334 (2·7)	0·02
Other knee reasons[¶]	6,255 (1·8)	89 (2·2)	213 (1·7)	0·14

[*] Note that more than one diagnosis could be indicated by the clinician on the form so categories are not mutually exclusive of each other·

[†] Inflammatory Arthritis for hips combines diagnoses of *Seronegative and Seropositive rheumatoid arthritis, Other Inflammatory Arthropathy, Ankylosing Spondylitis*, and *Psoriatic Arthropathy*·

[‡]All Trauma includes *Chronic Trauma, Fractured acetabulum, Fractured neck of femur, Acute Trauma of Neck of Femur, Previous Hip Trauma Not Specified, Failed internal fixation, Other hip trauma*·

[§] Other hip reasons include *Slipped Upper Femoral Epiphysis*, *Previous Arthrodesis, previous infection, Failed Hemi arthroplasty, previous non-trauma related surgery*, and *Other* indicated reasons for primary hip replacement·

[‖] Inflammatory Arthritis for knees combines diagnoses of *Rheumatoid Arthritis, Seronegative and Seropositive rheumatoid arthritis, and Other Inflammatory Arthropathy*·

[¶] Other knee reasons include *failed internal fixation, previous arthrodesis, trauma, previous infection, avascular necrosis, previous trauma, and Other* indicated reasons for primary knee replacement·

Table 3 Patient characteristics at time of first primary hip and knee joint surgery, broken down by ethnic group and gender, for patients with a primary diagnosis of osteoarthritis only

	Number of first primary hip replacements by Ethnic group, gender and patient factor. Percentage of Ethnic group shown in brackets·							
	Females				**Males**			
	White n=172,968	**Black n=818**	**Asian n=1,087**	**P-value**	**White n=116,960**	**Black n=649**	**Asian n=843**	**p-value**
Age group (years)								
Under 40	1,105 (0·6)	50 (6·1)	44 (4·1)		1,211 (1·0)	48 (7·4)	57 (6·8)	
40-49	4,998 (2·9)	134 (16·)	79 (7·3)		5,452 (4·7)	166 (25·6)	103 (12·2)	
50-59	20,534 (11·9)	156 (19·1)	181 (16·7)		17,939 (15·3)	161 (24·8)	190 (22·5)	
60-69	51,056 (29·5)	180 (22·0)	325 (29·9)		38,481 (32·9)	113 (17·4)	226 (26·8)	
70-79	64,510 (37·3)	228 (27·9)	336 (30·9)		40,523 (34·7)	130 (20·0)	213 (25·3)	
80 or more	30,765 (17·8)	70 (8·6)	122 (11·2)	<0·001	13,354 (114)	31 (4·8)	54 (6·4)	<0·001
Area Deprivation based on IMD 2010†								
Quintile 1 (most deprived)	22,113 (13·0)	308 (37·8)	214 (19·9)		14,048 (12·2)	239 (37·2)	195 (23·4)	
Quintile 2	29,958 (17·6)	21 (25·9)	222 (20·7)		19,598 (171)	186 (28·9)	174 (20·6)	
Quintile 3	38,650 (22·7)	136 (16·7)	259 (24·1)		26,136 (22·8)	97 (15·1)	164 (20·9)	
Quintile 4	40,804 (24·0)	86 (10·6)	181 (16·9)		28,600 (24·9)	53 (8·2)	158 (19·0)	
Quintile 5 (least deprived)	38,867 (22·8)	74 (9·1)	198 (18·4)	<0·001	26,572 (23·1)	68 7(10· 6)	142 (171)	<0·001
No· with missing IMD 2010 (% of all female or male HR for ethnic group)	*2,576 (1·5)*	*3 (0·4)*	*13 (1·2)*		*2,006 (1·7)*	*6 (0·9)*	*10 (1·2)*	
ASA grade								
P1 - Fit and healthy	25,899 (15·0)	137 (16·8)	187 (17·2)		22,172 (19·0)	205 (31·6)	201 (23·8)	
P2 - Mild disease not incapacitating	121,248 (70·1)	541 (66·1)	749 (68·9)		76,817 (65·7)	373 (57·5)	528 (62·6)	
P3/P4/P5 - Incapacitating or more severe	25,821 (14·9)	140 (17·1)	151 (13·9)	=0·030	17,971 (15·4)	71 (10·9)	114 (13·5)	<0·001
	Number of first primary knee replacements by Ethnic group, gender and patient factor. Percentage of Ethnic group shown in brackets·							
	Females				**Males***			
	White n=186,439	**Black n=2,899**	**Asian n=8,098**	**p-value**	**White n=144,624**	**Black n=998**	**Asian n=3,972**	**p-value***
Age group (years)								
Under 40	341 (0·2)	9 (0·3)	15 (0·2)		3,472 (2·4)	63 (602)	67 (1·7)	
40-49	4,192 (2·3)	111 (3·8)	205 (2·5)					
50-59	23,085 (12·4)	471 (16·3)	1,508 (18·6)		17,903 (12·4)	130 (13·1)	500 (12·6)	
60-69	57,361 (30·8)	1,050 (36·2)	3,109 (38·4)		51,318 (35·5)	301 (30·3)	1,279 (32·3)	
70-79	71,111 (38·1)	1,074 (37·1)	2,782 (34·4)		53,564 (37·1)	388 (39·4)	1,711 (43·1)	
80 or more	30,349 (16·3)	184 (6·4)	479 (5·9)	<0·001	18,367 (12·7)	109 (11·1)	408 (10·4)	<0·001
Area Deprivation based on IMD 2010†								
Quintile 1 (most deprived)	28,210 (15·2)	1,319 (46·3)	2,234 (28·0)		20,212 (14·2)	414 (42·0)	1,132 (287)	
Quintile 2	34,325 (18·6)	839 (29·2)	2,121 (26·5)		25,837 (18·1)	275 (27·9)	985 (25·0)	
Quintile 3	41,444 (22·6)	386 (13·4)	1,640 (19·9)		32,190 (22·3)	149 (15·1)	769 (19·5)	
Quintile 4	41,546 (22·6)	208 (6·8)	1,079 (13·7)		33,835 (23·4)	81 (8·2)	546 (13·9)	
Quintile 5 (least deprived)	38,278 (20·9)	124 (4·4)	958 (11·9)	<0·001	30,526 (21·4)	66 (6·7)	508 (12·9)	<0·001
No· with missing IMD 2010 (% of all female or male KR for ethnic group)	*2,636 (1·5)*	*23 (0·7)*	*66 (0·8)*		*2,024 (1·4)*	*13 (1·3)*	*32 (0·8)*	
ASA grade								
P1 - Fit and healthy	22,169 (11·9)	261 (9·0)	761 (9·4)		22,002 (15·2)	127 (12·7)	416 (10·5)	
P2 - Mild disease not incapacitating	135,513 (72·7)	2,094 (722)	6,021 (74·4)		100,359 (69·4)	668 (66·9)	2,752 (69·3)	
P3/P4/P5 - Incapacitating or more severe	28,757 (15·4)	544 (18·8)	1,316 (16·3)	<0·001	22,263 (15·4)	203 (20·3)	804 (20·2)	<0·001

Notes:

* Age categories *Under 40* and *40-49* combined to *Under 50* for male knee primaries as expected frequencies in chi squared test of association between age category and ethnic group fell below 5 in the original lowest age category·

† Area deprivation percentages shown are based on the distribution of non-missing IMD cases·

Table 4 Prosthesis fixation method for osteoarthritis first hip and knee replacement patients stratified by age-group, gender and ethnic group[*]

	Number of first hip replacement patient by Ethnic group and gender (%) [n=288,689]							
	Females				Males			
	White n= 170,379	Black n=815	Asian n=1,074	p-value	White n=114,945	Black n=643	Asian n=833	p-value[†]
Hip fixation method (<70 years)								
Cemented	22,013 (28·8)	71 (13·7)	142 (22·8)		13,496 (21·8)	49 (10·1)	90 (15·8)	
Uncemented	36,111 (47·2)	324 (62·7)	311 (50·0)		29,656 (47·9)	267 (55·2)	300 (52·6)	
Hybrid/ Reverse hybrid	13,982 (18·3)	78 (15·1)	130 (20·9)		8,954 (14·5)	46 (9·5)	81 (14·2)	
Resurfacing	4,346 (5·7)	44 (8·5)	39 (6·3)	<0·001	9,807 (15·8)	122 (25·2)	99 (17·4)	<0·001
Hip fixation method (≥ 70 years)								
Cemented	54,681 (58·2)	133 (44·6)	244 (54·0)		27,186 (51·3)	57 (35·9)	108 (41·1)	
Uncemented	22,681 (24·2)	100 (33·6)	115 (25·4)		16,247 (30·6)	72 (45·3)	107 (40·7)	
Hybrid/ Reverse hybrid/ Resurfacing[3]	16,565 (17·6)	65 (21·8)	93 (20·6)	<0·001	9,599 (18·1)	30 (18·9)	48 (18·3)	<0·001
	Number of first knee replacement patients by Ethnic group and gender (%) [n=342,208]							
	Females				**Males**			
	White n=183,786	**Black n=2,876**	**Asian n=8,031**	**p-value**	**White n=142,590**	**Black n=985**	**Asian n=3,940**	**p-value[†]**
Knee fixation method (<70 years)								
Cemented	67,461 (80·6)	1,427 (87·8)	4,098 (85·4)		56,419 (78·7)	405 (83·0)	1,493 (81·4)	
Uncemented/hybrid	4,765 (5·7)	98 (6·0)	215 (4·5)		4,706 (6·6)	36 (7·4)	141 (6·4)	
Patellofemoral/Unicondylar	11,485 (13·7)	101 (6·2)	487 (10·1)	<0·001	10,525 (14·7)	47 (9·6)	224 (12·2)	0·001
Knee fixation method (≥ 70 years)								
Cemented	90,684 (90·6)	1,153 (92·2)	2,981 (92·3)		62,574 (88·2)	446 (89·7)	1,906 (90·6)	
Uncemented/hybrid	5,136 (5·1)	68 (5·4)	153 (4·7)		4,238 (6·0)	31 (6·2)	143 (5·0)	
Patellofemoral/Unicondylar	4,255 (4·3)	29 (2·3)	97 (3·0)	<0·001	4,128 (5·8)	20 (4·0)	93 (4·4)	0·007

[*] Based on the complete case sample for hips and knees· [†]After collapsing prosthesis categories indicated as original cell expected frequencies were below 5·

Table 5 Odds ratios for receiving an uncemented hip replacement by ethnic group adjusting for patient and trust related covariates (n=224,561)

		Model A	Model B*	Model C†
Variables		**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Ethnicity	**White**	ref	ref	ref
	Black	2·76 (1·94–3·93)	1·86 (1·30–2·66)	1·43 (1·11–1·84)
	Asian	1·60 (1·23–2·08)	1·21 (0·90–1·63)	1·01 (0·84–1·21)
Gender	**Female**		ref	ref
	Male		1·37 (1·31–1·43)	1·50 (1·43–1·58)
ASA Grade	**Grade1**		ref	ref
	Grade 2		0·96 (0·86–1·07)	1·01 (0·91–1·13)
	Grade 3/4/5		0·83 (0·71–0·97)	0·89 (0·78–1·02)
Age Group	**Under 40**		19·56 (12·36–30·97)	46·98 (33·20–66·47)
	40-49		16·99 (12·17–23·73)	36·66 (26·89–49·98)
	50-59		10·43 (8·19–13·28)	20·10 (15·39–26·25)
	60-69		4·13 (3·49–4·89)	6·29 (5·21–7·60)
	70-79		1·69 (1·56–1·84)	1·97 (1·78–2·17)
	80 and over		ref	ref
Area deprivation				
Most deprived	**Quintile 1**		0·85 (0·68–1·05)	0·77 (0·67–0·88)
	Quintile 2		0·95 (0·80–1·14)	0·87 (0·78–0·97)
	Quintile 3		0·97 (0·83–1·14)	0·94 (0·85–1·04)
	Quintile 4		0·92 (0·81–1·04)	0·95 (0·88–1·03)
Least deprived	**Quintile 5**		ref	ref
Trust (%) uncemented				
Lowest	**Quartile 1**			0·02 (0·01–0·04)
	Quartile 2			0·07 (0·05–0·10)
	Quartile 3			0·19 (0·14–0·25)
Highest	**Quartile 4**			ref
Wald test for added terms		p-value<0·001	p-value<0·001	p-value<0·001

* Multivariable odds ratios adjusted for gender, ASA grade, IMD score and age-group·

† Multivariable odds ratios adjusted for covariates in model B plus the proportion of uncemented primaries carried out within the local trust where primary took place·

Table 6 Logistic regression Models A-E with restricted sample size for BMI subset (n= 44,001)

	Odds Ratio (95% CI) estimates for logistic regression models of uncemented hip replacement on ethnic group and adjusted for covariates shown				
Variables	**Model A***	**Model B†**	**Model C‡**	**Model D§**	**Model E‖**
Ethnic Group					
White	ref	ref	ref	ref	ref
Black	2·27 (1·49–3·47)	1·42 (0·90–2·25)	1·32 (0·80–2·17)	1·32 (0·80–2·18)	1·32 (0·85–2·04)
Asian	1·71 (1·03–2·83)	1·27 (0·77–2·11)	1·11 (0·72–1·72)	1·12 (0·72–1·73)	1·12 (0·80–1·56)
Gender					
Female		ref	Ref	ref	ref
Male		1·45 (1·34–1·57)	1·63 (1·50–1·77)	1·63 (1·50–1·77)	1·62 (1·54–1·70)
ASA Grade					
Grade 1		ref	ref	ref	ref
Grade 2		0·89 (0·78–1·01)	0·87 (0·73–1·01)	0·86 (0·74–1·01)	0·86 (0·79–0·92)
Grade 3/4/5		0·68 (0·54–0·86)	0·71 (0·55–0·88)	0·70 (0·55–0·89)	0·69 (0·63–0·76)
Age-Group					
Under 40		22·06 (12·62–38·57)	58·99 (31·52–110·42)	59·26 (31·55–111·31)	59·80 (39·27–91·06)
40-49		19·87 (12·56–31·45)	46·48 (29·31–73·69)	48·41 (29·27–73·58)	45·70 (37·57–55·59)
50-59		11·49 (8·51–15·51)	23·81 (16·81–33·73)	23·73 (16·76–33·59)	23·34 (20·90–26·07)
60-69		4·27 (3·50–5·21)	6·63 (5·17–8·49)	6·61 (5·16–8·46)	6·51 (5·99–7·08)
70-79		1·75 (1·56–1·97)	1·97 (1·71–2·26)	1·97 (1·71–2·26)	1·94 (1·80–2·10)
80 and over		ref	ref	ref	ref
Area Deprivation					
(most) Quintile 1		0·94 (0·70–1·28)	0·90 (0·70–1·15)	0·90 (0·71–1·15)	0·90 (0·83–0·98)
Quintile 2		0·93 (0·72–1·19)	0·90 (0·74–1·09)	0·90 (0·74–1·10)	0·90 (0·83–0·97)
Quintile 3		0·89 (0·71–1·12)	0·88 (0·73–1·05)	0·88 (0·73–1·05)	0·88 (0·81–0·94)
Quintile 4		0·85 (0·72–1·01)	0·89 (0·78–1·02)	0·89 (0·78–1·02)	0·89 (0·83–0·96)
Quintile 5		ref	ref	ref	ref
Proportion of uncemented primaries done within local trust					
(lowest 25%) Quartile 1			0·01 (0·01–0·03)	0·01 (0·01–0·03)	0·01 (0·01–0·02)
Quartile 2			0·06 (0·03–0·12)	0·06 (0·03–0·12)	0·06 (0·06–0·07)
Quartile 3			0·20 (0·11–0·37)	0·20 (0·11–0·37)	0·20 (0·19–0·22)
Quartile 4			ref	ref	ref
PROMS EQ-5D-3L mobility item					
No problems walking about				ref	ref
Some problem walking about				0·88 (0·77–1·01)	0·87 (0·78–0·97)
Confined to bed				0·81 (0·51–1·27)	0·81 (0·52–1·25)
BMI					
Underweight					0·81 (0·66–0·99)
Normal					ref
Overweight					1·05 (0·98–1·12)
Obese					1·06 (0·99–1·14)
Wald test for added terms	p-value=0·001	p-value<0·001	p-value<0·001	p-value=0·153	p-value=0·027

* Unadjusted odds ratio for ethnicity·

† Multivariable odds ratio adjusted for gender, ASA grade, IMD score, and age-group·

‡ Multivariable odds ratio adjusted for covariates in Model B plus the proportion of uncemented primaries carried out within the local trust where the primary took place·

§ Multivariable odds ratio adjusted for covariates in Model C plus PROMS preoperative EQ-5D mobility indicator·

‖ Multivariable odds ratio adjusted for covariates in Model D plus patient BMI category·